Letter of Intent to Measure the Fierz Interference Term, b, in Neutron Beta Decay

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This letter outlines our plans to perform a measurement of the Fierz interference term, b, in neutron beta decay at the High Flux Isotope Reactor at Oak Ridge National Laboratory. The decay rate for neutron beta decay, $n \to e + p + \bar{\nu}_e$, is given by:

$$\frac{dW}{d\Omega} = \rho(E)\left[1 + P_n\left(A\beta Cos(\vartheta_{es}) + BCos(\vartheta_{\nu s})\right) + aCos(\vartheta_{e\nu}) + b\frac{m}{E}\right]$$

where $\rho(E)$ is the phase space factor as a function of the electron energy E; P_n is the neutron polarization; and ϑ_{es}, $\vartheta_{\nu s}$, and $\vartheta_{e\nu}$ are the angles between the electron direction and the neutron polarization direction, the neutrino direction and the neutron polarization direction, and the electron direction and the neutrino direction respectively. The coefficient b modifies the shape of the electron energy spectrum for unpolarized neutrons, $\frac{dW}{d\Omega} = \rho(E)\left(1 + b\frac{m}{E}\right)$, from phase space. A non-zero value of b requires the existence of scalar (S) or tensor (T) weak interactions in addition to the dominant vector (V) and axial-vector (A) weak interactions. The Fierz term has been measured to be zero with an accuracy of .05 in nuclear beta decays, but has never been measured in neutron beta decay. The goal of this letter of intent is to measure the Fierz term with an accuracy of 0.5% in neutron beta decay.

The measurement will be performed using a new type of spectrometer shown in Figure 1. The spectrometer uses a magnetic field to guide the e and p from neutron beta decay to a pair of segmented silicon (Si) detectors. The decay volume is at a potential of ~30 kV so that the protons have approximately 30 keV of kinetic energy when they reach the grounded Si detectors. The Si detectors have thin entrance windows that allow the detection of both the proton and electron. The ability to detect coincidences greatly suppresses backgrounds and allows the measurement of residual backgrounds. The use of a magnetic field to guide the decay products to the segmented Si detectors provides 4π detection of both electrons and protons and suppression of backgrounds by use of coincidences. The segmentation of the Si detectors reduces backgrounds further because e-p coincidences can occur only between conjugate detectors. The magnetic field in the decay region is stronger, 4 T, than at the detectors, 1 T. The field expansion causes the particle trajectories to be more parallel to the magnetic field than if the field were constant. The probability of electron backscattering is reduced to about 20%. A backscattered electron experiences a magnetic field that increases its strength as the electron moves back towards the decay region and most of the backscattered electrons are reflected back to the detector that was struck first. In any event, the electrons can only escape being contained by one of the Si detectors if they diffuse sideways in the process of multiple backscatterings. The detectors would consist of 2 mm thick single crystal Si wafers divided into an array of 25 1-cm^2 pixels. The maximum radius of curvature of electrons and protons at the detector is 4 mm. The beam is imaged at each detector, and the fiducial length is determined by the point at which the charged particles strike the detector rather than by material apertures. Imaging the beam provides another method to determine any small residual backgrounds.

The work described above has two purposes:

1. To perform a measurement of the Fierz interference term in neutron beta decay with an accuracy of 0.5%.
2. To develop and demonstrate the technology of the new approach to the experimental study of neutron beta decay.

We intend to apply this technology to future experiments at a pulsed cold neutron source to measure the electron-spin correlation, A, the neutrino spin correlation, B, and the electron-neutrino correlation, a, as well as to further improving the accuracy in b.

Each of the institutions signing this letter of intent will seek funding from its sponsors in early 2002. We intend to investigate technical problems in 2002. We will measure the time resolution of the Si detectors using radioactive sources. It is necessary to know the time resolution for low energy electrons in order to determine the footprint of the apparatus to be used at a pulsed source, where it will be necessary to determine which detector was struck first from timing between coincident electrons. We estimate that the time resolution is ~1 nsec for 100 KeV electrons. We will perform bench tests to study the problems of breakdown and sparks in the spectrometer before committing to an engineering design of the apparatus. We will obtain 25-cm^2 segmented arrays of Si detectors, and develop electronics to read out the detectors. We intend to mount an experiment at HIFR in 2003 and obtain a sample of 10^7 events. The apparatus would be approximately 1 meter in diameter and 3 meters long. The footprint of the experiment would require sufficient access space for replenishing cryogens and servicing the apparatus.

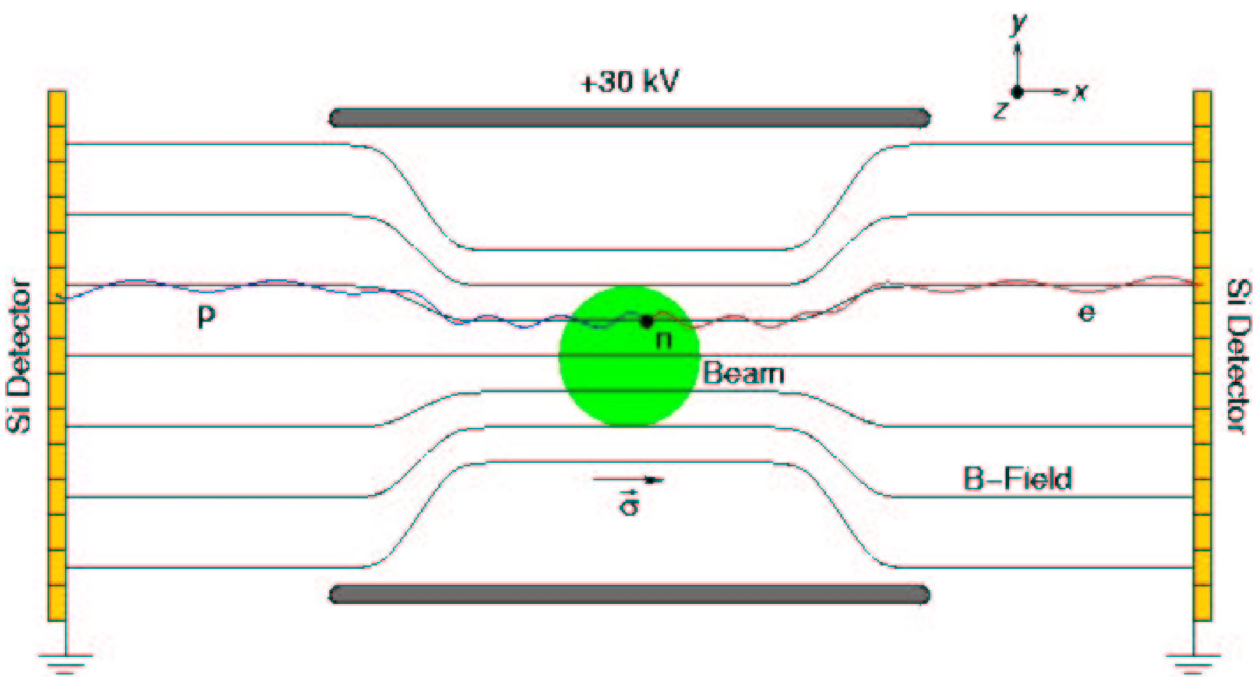

Figure 1. Spectrometer for beta decay correlation measurements.